

KlimaLink Standard Methodology – Calculation of emissions from aviation

Version 1.1

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Foreword

KlimaLink has set itself the aim of providing the tourism industry with a platform that makes the CO₂e emissions of various travel components within the tourism sector available in one central location.

The demand for a standardised method of calculating carbon emissions has grown significantly within the industry, and both business travellers and holidaymakers are increasingly asking about the actual carbon footprint of their journeys.

There are already various methods for calculating greenhouse gas emissions in the tourism sector. However, these do not define CO₂e emissions in a standardised manner and determine emissions using different approaches and levels of accuracy. The aim of KlimaLink is to make CO₂e emissions available to all users in the tourism sector in accordance with the following criteria, within a standard comprising various methods:

- CO₂e emissions are recorded systematically and with a high degree of accuracy.
- The CO₂e emissions from different travel components (flights, hotel stays, rail journeys, etc.) can be compared and categorised.
- The calculations are accurate enough to show travellers options for reducing carbon emissions even before they book.
- The calculations are accurate enough to enable comparisons of various types of combined travel products based on their absolute CO₂e emissions.
- The various methods rely entirely on travel input data that is available as standard within the travel industry's systems at tour operators and travel agents.
- The standard provides a unique CO₂e value for every input of travel components worldwide (flights, train journeys, hire cars, hotel stays, etc.). To this end, the individual methods specify fallback hierarchies which, in descending tiers (method variants), require increasingly less specific input data in order to always deliver the best possible result under the given circumstances.

This standard is based on the standard for CO₂e emissions calculation for business travel issued by the German Travel Management Association (VDR Standard, latest version from 2016). The CO₂e calculation methods in this standard were developed by atmosfair specifically to meet the requirements of CO₂e reporting for business travel. For the purposes of KlimaLink and the differing requirements in tourism compared with business travel (including ex-ante estimation at the time of booking the trip rather than ex-post reporting for companies' CO₂e balances of companies), the Institute for Sustainable Tourism (Inatour) has further developed the VDR Standard on behalf of Futouris e.V. and with technical and methodological support from atmosfair. Other committed member companies of KlimaLink also contributed to this work. In the process, the methodological and scientific content was also updated to reflect the current state of research where necessary.

The distinctive feature of the KlimaLink Standard lies in the calculation of emission values (ex-ante) per person in advance. Data from previous years enable a concrete estimate of future emission values. This makes the emissions associated with travel – known as travel carbon footprints – visible even before booking, thereby serving as a potential advisory and decision-making aid for travel agents and customers within sales channels. Those in the tourism industry can access these emissions figures via the emissions data platform made freely available by KlimaLink for this purpose.

This standard for calculating air travel has been drawn up in accordance with the ISO 14083 standard. The standard, which forms the basis of the 'Count Emissions' Directive coming into force in the EU, serves as a uniform standard for calculating greenhouse gas emissions in passenger and freight transport. It establishes EU-wide comparable guidelines to enable the objective assessment of CO₂e balances for transport operations.

1. Requirements for the standard

1.1. Completeness and relevance

The KlimaLink standard covers the key areas of the tourism value chain: hotels, rail, air travel, cars, buses and ships. It captures the significant CO₂e emissions whilst excluding negligible ones, such as local public transport at the destination.

1.2. Applicability and scientific rigour

The calculation of CO₂e emissions from transport and accommodation is intended to be applicable worldwide. This concerns the ability to determine the CO₂e emissions of any journey – whether for tourism or business purposes – anywhere in the world, with a minimum level of accuracy based on the availability of data and the relevance of the travel component being calculated.

The aim is not to develop a method that is entirely scientifically underpinned. Given the existing uncertainties surrounding individual elements of the calculation methods, this would be unrealistic, as the availability and accuracy of data are subject to constant change. Rather, the aim is to enable a sufficiently good calculation (minimum accuracy) that can be supported by a large number of stakeholders and thus facilitates the objective – a uniform calculation across all service providers.

1.3. Minimum accuracy

The calculation methods set out in this document are sufficient to achieve the minimum accuracy described.

1.3.1. Transparency

The calculation methods, the factors to be taken into account and possible data sources are described within the framework of this standard. This enables every stakeholder to check the CO₂e emissions of their journey and to have the calculation method explained to them online, at a travel agency or at other points of sale.

1.3.2. Independence

The input data used to calculate emissions should, as far as possible, come from independent sources and be verified or certified by third parties. Direct provision of data from service providers (e.g. hotels, car hire companies or railway operators) is also possible, provided that this data has been verified or certified by third parties. KlimaLink is able to carry out plausibility checks. However, comprehensive quality control, as is customary with certifiers or other auditing firms, cannot be carried out due to time and cost constraints. General approaches such as scope definitions and standard emission factors are based, as far as possible, on the IPCC¹, the GHG Protocol² and other internationally recognised organisations.

¹ Intergovernmental Panel on Climate Change (IPCC)

² Greenhouse Gas Protocol

1.3.3. Further Development

The standard and the methods underpinning it are subject to continuous development. Adjustments, updates and improvements are both desirable and necessary. Further development takes place in working groups comprising experts from the member organisations.

1.4. Operational system boundaries

1.4.1. Travel-specific emissions

When calculating travel emissions, the first step is to consider the emissions arising from the provision of the relevant service and which therefore relate specifically to the journey (e.g. emissions from kerosene consumption during a flight, including the upstream oil supply chain). In contrast, emissions associated with infrastructure (e.g. facility management of the airport building) and means of transport (e.g. construction and maintenance of the aircraft) do not arise exclusively in the course of the journey under consideration, but rather as part of general investments that benefit all users. The inclusion of these indirect emissions in the calculation of a journey's carbon footprint is not currently taken into account in the methods described.

1.4.2. Upstream emissions

The combustion of raw materials, power fuels or motor fuels to generate useful energy results in direct climate-impacting emissions, the type and quantity of which depend on the fuel used, as well as on the technology and efficiency of the facilities in the upstream chain (e.g. oil extraction, logistics and refining). These can be attributed to tourism users and must be recorded in the KlimaLink standard with appropriate accuracy wherever possible.

1.4.3. Non-CO₂ emissions

The combustion of fuels in aviation generates, in addition to CO₂, other climate-impacting emissions such as nitrogen oxides (NO_x) or soot, which, through their physical and chemical properties in the atmosphere, have a positive or negative effect on radiative forcing. Whilst the climate impact of non-CO₂ emissions from combustion processes near the ground (e.g. car journeys, train journeys, hotels including upstream emissions) is negligible compared to that of CO₂, non-CO₂ emissions in higher atmospheric layers during air travel have a significant effect on the Earth's radiative balance. Generally, the term CO₂e³ is used throughout the standard in reference to CO₂e.

1.5. Reporting

The KlimaLink Standard determines ex-ante (prior to departure) emission factors for individual components of a holiday or business trip based on the information provided in the calculation request.

1.5.1. Flight

An emission factor corresponds to the CO₂e value of a flight for one person on a specific route (city pair). Based on the information contained in the calculation request and the source data underlying the calculation, this emission factor may be specific to

³CO₂ equivalents, the unit of measurement used to standardise the climate impact of different greenhouse gases.

- the aircraft type
- the airline
- the booking class

If one or more of these details are missing, an approximation is sought by taking the average across all relevant options (e.g. across all airlines serving the specific city pair).

2. Calculation of flight emissions

Calculating flight emissions is complex, as many different factors influence greenhouse gas emissions and their impact on the climate (including, amongst other factors, payload, distance and flight profile). Furthermore, calculating the proportionate emissions per passenger is a complex process. Factors such as seating configuration, load factor and cargo play a role here.

To complicate matters further, actual fuel consumption figures for flights are not publicly available, as they constitute competitively sensitive data. The possible methods therefore rely on calculations that use data available on the market to reflect the actual values as accurately as possible.

Finally, in the aviation sector, there is also the ‘non-CO₂ climate impact’, which is caused by aviation emissions at high altitudes.⁴ A key driver here is the warming effect of contrails and cirrus clouds caused by flights. This warming effect also depends on factors such as day/night and flight altitude, as well as the climate zone, but can be estimated as an average across all these factors.

For business and private travel undertaken by aeroplane, greenhouse gas emissions from the flight itself usually account for the largest share of total emissions – on average around 80 per cent. It is therefore essential that the methodology used for flights reflects the actual CO₂ emissions as accurately as possible, as otherwise it will significantly compromise the accuracy of the overall result.

2.1. Consideration of non-CO₂ emissions in aviation

2.1.1. Background⁵

Global aviation accounts for around 3.5 per cent of anthropogenic global warming to date. The international scientific community assesses all factors by which the aviation industry has contributed to climate change since its inception.⁶ This includes emissions of carbon dioxide (CO₂), nitrogen oxides (NO_x) and the effects of contrails and contrail cirrus clouds.

It is evident that only one third of aviation’s climate impact is attributable to CO₂ emissions. The remaining two thirds of aviation’s climate impact are due to non-CO₂ effects. Contrails

⁴ These additional climate impacts are referred to as non-CO₂ emissions and affect the part of the flight that takes place at high altitudes. Together with the pure CO₂ emissions, they have, on average, a greater global warming potential by a certain factor than the CO₂ emissions from fuel consumption alone. This is referred to as the ‘uplift factor’.

⁵ Source of this chapter: German Aerospace Centre (DLR).

⁶ Approximately half of the total cumulative CO₂ emissions have been generated in the past 20 years alone.

and the resulting contrail cirrus clouds are the most significant factor here. This is due to particle emissions of all kinds emitted by aircraft engines. Under suitable ambient temperature and humidity conditions, these act as condensation nuclei for small supercooled water droplets, which freeze into ice crystals and become visible in the sky as contrails. Under cold, humid conditions at altitudes of around 8 to 12 kilometres, the ice crystals in contrails can persist for several hours and form contrail cirrus clouds.

Depending on the time of day and the surface below, these clouds can have a warming or cooling effect locally. However, numerous research studies show that the warming effect predominates globally.

Nitrogen oxide emissions from air traffic lead to additional ozone in the upper troposphere and lower stratosphere, where they warm the climate. In addition, emissions such as water vapour, soot, aerosols and sulphate aerosol particles make further, smaller contributions relevant to the climate. If all non-CO₂ effects are taken into account, aviation's contribution to global warming to date is estimated at around 3.5 per cent. The path towards aviation that is as climate-friendly as possible must take all these factors relating to the climate impact of flying into account.

2.1.2. Scientific studies and the current state of research

A large number of scientific studies have been investigating the above-mentioned effects since 1990. Whilst there is still some variation in the resulting uplift factor for high altitudes, However, the key effects have been identified since around 2010 and their quantitative impacts have already been narrowed down, meaning that for the past decade the uplift factor has been consistently reported as lying within the range of 2 to 4, with a mean value of 3.

Research has now reached a stage where the defined framework conditions and assumptions influence the uplift factor more than the residual uncertainties in atmospheric physics. These include, for example:

The chosen methods for calculating the uplift factor: including metrics such as Global Warming Potential (GWP), Radiative Forcing (RF) or Global Temperature Potential (GTP)

The choice of time horizon regarding the climate effects of contrails for comparing CO₂e emissions: e.g. 20, 50 or 100 years.

The discount rate used to spread the future harmful effects of CO₂ emissions over long time periods.

Table1 shows a selection of high-quality studies from the last 20 years.

1. *Table1 Research findings on the uplift factor*

.	Author	Year	Metric	Uplift factor	Mean
IPCC SR aviation	Penner et al.	1999	RF ₁₉₉₂	2.0 – 4.0	2.7
IPCC FOAR	Solomon et al.	2007	RF ₂₀₀₀	1.9 – 4.7	-
MPI	Graßl, Brockhagen	2007	RF	1.9 – 4.7	-
UBA	Project Team	2008	RFI	2–5	3

Atmospheric Environment	Lee et al.	2010	GWP ₂₀₋₁₀₀	1.9–4.8	-
UBA	Project Team	2019	various	-	3
EASA for the EC	Project Team (including DLR, CICERO, Manchester University)	2020	various	-	3
Atmospheric Environment	Lee et al.	2020	GWP* ₁₀₀	-	3

Whilst in the 1990s only broad ranges could be specified, research over the last ten years has established a mean value of 3. In doing so, normative assumptions were made which are regarded as an established political consensus in international climate policy (the Kyoto Protocol and the Paris Agreement) and by the IPCC.

Many well-known, reputable organisations have publicly stated their position on this matter:

UBA	Uplift Factor 3 ⁷
EASA	Uplift Factor 3 ⁸
DLR	Uplift factor 3 ⁹

In conclusion, it can be stated that the integration of non-CO₂ emissions and their climate impacts must be incorporated into the calculation method for a flight standard. The uplift factor should be based on internationally recognised scientific findings. Based on the established state of research over the past decade, the uplift factor averages 3 and is incorporated accordingly into the KlimaLink flight method.

However, as the non-CO₂ effects of individual flights vary considerably (e.g. depending on the route), a specific calculation of non-CO₂ emissions per flight is, in principle, desirable. At present, however, there is still no reliable database for this. Should relevant new study results become available that enable the precise calculation of non-CO₂ emissions for specific flights, the calculation methods used by KlimaLink will be adjusted accordingly.

2.2. Description of the methodology

The factors described below determine the emissions from air travel. They represent a minimum set of factors to be taken into account here. Other factors can, in some cases, significantly alter fuel consumption; however, they either cannot be captured ex ante or are, on the whole, not significant enough to justify the additional effort involved in data collection and calculation. These factors, which are not taken into account in the KlimaLink flight method, include, amongst others:

- General weather conditions and associated air currents (jet stream, etc.).
- Economical flight operations: slow flight or SDA (Slow Descent Approach).
- The state of maintenance of the aircraft in question and its engines.

⁷ <https://www.umweltbundesamt.de/publikationen/klimawirkung-des-luftverkehrs> and https://uba.co2-rechner.de/de_DE/

⁸ <https://www.easa.europa.eu/en/downloads/120860/en>

⁹ <https://www.dlr.de/de/forschung-und-transfer/themen/klimavertraegliches-fliegen/klimawirkung-luftverkehr>

- Specific local airport requirements, such as the fastest possible climb for noise abatement reasons.
- Emissions resulting from airport operations (air conditioning, lighting, baggage/passenger transport, etc.)¹⁰
- Excess weight or luggage carried by passengers.¹¹

2.2.1. Distance, chosen flight route and detours

The distance travelled has a significant impact on fuel consumption and, consequently, on the volume of CO₂e emissions. It is therefore essential to determine this as accurately as possible. Generally speaking, airlines aim to fly the shortest possible route between two cities. In practice, however, the prescribed flight route is not a straight line. Furthermore, unforeseen factors can cause the distance flown to increase. The distance between a city pair is therefore determined using the great circle distance, to which a detour is added. Empirical studies have shown that the absolute detour is largely independent of distance, as shorter flights incur relatively larger detours than long-haul flights. The flight calculation method therefore uses three standard detour lengths, which depend on three distance classes of the great circle distance and are specified by the ICAO in its method for flight calculations.

The influence of distance on specific fuel consumption is not linear. Section 1 C,

Input variables and calculation formulas, explains in detail how the method addresses this challenge. To do so, it requires a sufficiently fine-meshed grid of standard distances for all aircraft types. The following requirements therefore apply to this grid.

Coverage: At least 32 standard distances for flight ranges between 250 km and 18,000 km (to accommodate future ultra-long-haul flights).

Resolution: From 0 to 3,000 km, a maximum distance of 250 km between adjacent standard distances; from 3,000 km to 8,000 km, a maximum distance of 500 km; and from 8,000 km onwards, a maximum distance of 1,000 km.

2.2.2. Specific aircraft type

Fuel consumption depends heavily on the aircraft type. Each aircraft is designed and optimised by the manufacturer for a specific range and passenger capacity. Operating outside these specifications generally results in increased kerosene consumption per passenger. Consequently, depending on the airline and the aircraft it operates, CO₂ emissions per passenger can vary significantly on the very same city pair. This factor is taken into account in the emissions calculation.

¹⁰ In accordance with ISO 14083, hub emissions may be disregarded if they are considered negligible (5.2.3.a); see the Fraport Environmental Statement 2020 <https://www.fraport.com/de/nachhaltigkeit/umwelt-und-klima/umweltmanagement.html> and IATA Airport Environmental Sustainability <https://www.iata.org/contentassets/d1d4d535bf1c4ba695f43e9beff8294f/airport-environmental-sustainability-policy.pdf>

¹¹ Instead of the previously assumed 100 kg for passengers and baggage, 105 kg is currently considered a more realistic figure.

Furthermore, aircraft manufacturers' portfolios consist of various aircraft families, each comprising several models.¹² These models, in turn, are available in different variants and are optimised for different passenger capacities or flight distances. The exact aircraft type is therefore taken into account in the CO₂e emissions calculation.

In practice, an aircraft type is defined by manufacturer, family, model and variant. The KlimaLink flight method therefore requires that aircraft types be recorded by manufacturer, family, model and variant for each flight and incorporated at this level of detail into the computer-model-based fuel consumption calculations for standard distances and payloads (e.g. Boeing 777-200ER; see also Section 5 on fuel weight, payload and flight profile). Restricting the data to family and model only, or to family only via aggregated hybrid aircraft, leads to deviations of up to +/- 30 per cent and is therefore too imprecise for this method.

In some cases, it is not possible to unambiguously identify the aircraft type from the booking data in flight reservation systems (flight number, date). Reasons for this include, for example, the airline not having recorded this in the flight schedules, or the flight schedules being unable to display the aircraft type. This gives rise to the following requirements for the method.

Coverage: Covers all aircraft types of commercial aircraft from all manufacturers in international aircraft classes A and B (MTOW > 14 tonnes) on which tourist flights are operated. As soon as new aircraft types are introduced, they must be included in the methodology (see the section '2.2.15' regarding updates).

- **Tier 1:** Aircraft types are recorded for each individual flight at the detailed level of manufacturer, family, model and variant, and are included at this level in the calculation of fuel consumption using computer models based on standard distances and standard payloads (see Section 5 on fuel weight, payload and flight profile).
- **Tier 2:** Alternatively, in cases where the aircraft type is not fully specified in the flight plans, the levels of detail regarding variant, model, family and manufacturer may be progressively omitted.
- **Tier 3:** If flight plans contain no information whatsoever on the aircraft type, fuel consumption per passenger and per 100 passenger-kilometres may, as a fallback, be calculated generically using average values from independent environmental compendia, such as those published by the German Federal Environment Agency (UBA), based on at least ten flight distance classes ranging from short-haul to ultra-long-haul.

2.2.3. Fitting with winglets / sharklets

Winglets or wingtips fitted to the wing tips improve the aircraft's aerodynamic properties and reduce fuel consumption. Reductions of up to approximately 3 per cent are possible. If an airline retrofits aircraft with winglets, this should be taken into account in the emissions calculation. However, not all aircraft types can be retrofitted with winglets.

¹² For example, for the Airbus A320 family (models A318, A319, A320, A321) or for the Boeing B737 NG family (models B737-600, B737-700, B737-800, B737-900)

When calculating fuel consumption for standard flights using a specific computer model (see Section 5 on fuel weight, payload and flight profile) and subsequently calculating CO₂e emissions per passenger for flights, it is therefore necessary to take into account for each flight or booking whether the aircraft in question has been retrofitted with winglets or not.

If, for a flight listed in the flight schedule, the aircraft type cannot be determined with regard to winglet fit, winglet ratios for the aircraft type used by the operating airline may be applied as a fallback for that flight. The winglet ratio indicates the percentage of the airline's aircraft of that type that are fitted with winglets. This ratio is then applied as an average value to the fuel savings previously determined by the computer model for all aircraft of that type operated by the airline.

2.2.4. Aircraft age and maintenance

Age affects an aircraft's fuel consumption. Two aspects must be taken into account here.

2.2.4.1. *Age of the aircraft*

Over the course of an aircraft's service life, signs of wear and tear as well as material fatigue can, for example, impair aerodynamics and lead to higher fuel consumption. This can be reduced or prevented through good maintenance. The flight method assumes that this is generally the case and therefore does not explicitly take the aircraft's age into account in the CO₂e calculation.

2.2.4.2. *Year of manufacture within a model variant*

The year of manufacture also influences fuel consumption. Particularly in the case of long-lasting models, newer aircraft may utilise better, more fuel-efficient technologies or materials that were not yet available in older models. Where differences arise due to the year of manufacture, it can be assumed that older aircraft will be retrofitted with the newer technologies, which tends to even out the differences. However, as long as no suitable data is available on the market, this aspect cannot be calculated with sufficient accuracy.

2.2.5. Fuel weight, payload and flight profile

A flight is divided into the phases of take-off, climb, cruise, descent and landing. Take-off and climb, in particular, require a great deal of kerosene. This is more significant for short-haul flights than for medium- and long-haul flights. Consequently, the relative fuel consumption per passenger is higher on short-haul flights than on medium-haul flights. Long-haul flights, on the other hand, have a higher specific consumption because the entire fuel load must be carried, and its heavy weight has a negative impact on overall consumption.

In practice, this is the most challenging part of the CO₂e calculation. The heavier the aircraft is on take-off and the longer the flight, the higher the absolute fuel consumption, with both factors having a distinctly non-linear effect on the result. If an aeroplane climbs at a steeper angle, it consumes more fuel, but in turn reaches the altitudes where air resistance decreases due to lower air density more quickly, which leads to fuel savings. Only once the payload (passengers and cargo) is known can the amount of fuel to be loaded be calculated as a first ap-

proximation; however, this in turn increases the take-off weight (in the same way as additional payload). Consequently, a simple, direct calculation of fuel requirements is only possible with a high margin of error. Computer models such as Eurocontrol's Base of Aircraft Data (BADA), piano-x or commercial Aircraft Performance Monitoring (APM) models take these dependencies into account through iterative calculations and can thus calculate the actual fuel consumption with a high degree of accuracy for each individual flight.

To achieve the stated objectives of the KlimaLink flight method, it is therefore necessary for the basis of the fuel consumption calculation to be, on the one hand, founded on many standard flights for which such detailed computer models have calculated fuel consumption. On the other hand, starting from these standard flights, simplifying interpolations can then be applied to the large number of daily flight calculations carried out by KlimaLink. In this way, the complexity of flights is taken into account appropriately without, in practice, resulting in a significant computational burden.

The KlimaLink flight method therefore requires that the fuel consumption figures for standard flights be grouped in a fine-meshed manner and calculated both according to various standard distances (see Section 1: Distance) and according to various standard payloads, on the basis of which the interpolation for the many real-world flights can then be carried out.

Fuel consumption on standard flights should be calculated using dedicated models from the aviation industry, which accurately represent the non-linear relationships between fuel weight, flight distance, payload and flight profile for all aircraft types across a range of distances and payloads. The formulae for calculating fuel consumption on standard flights and the interpolations based on them can be found in Section C.

2.2.6. Taxiing and reserve fuel

Before take-off, aircraft must taxi from the terminal to the runway, during which they consume fuel and emit CO₂e emissions that are not initially recorded in the flight profiles. The same applies to taxiing to the terminal after landing. The taxiing distance varies from airport to airport, so fuel consumption during taxiing also varies. Due to the relatively low weight involved, this effect can be taken into account with sufficient accuracy by applying a surcharge to the fuel consumption figure. For the average airports considered here, this is already factored into the fuel calculation of the dedicated computer models (see Section 5: Fuel Weight, Payload and Flight Profile).

Every aircraft must carry reserve fuel to allow for any deviations from the planned route. Reserve fuel increases the take-off weight and thus the CO₂e emissions of a flight – in some cases significantly – and must therefore also be calculated. Determining the required quantity involves the same level of complexity and similar dependencies as determining the actual fuel consumption and can accordingly be calculated using the computer models mentioned there for standard distances and payloads.

2.2.7. Seating (number of seats on board)

The choice of aircraft type determines the maximum number of seats on board. However, there are differences from airline to airline, and even within a single airline, regarding the total number of seats installed in a particular aircraft type. This must be taken into account precisely for each flight, as it, together with passenger load factor via payload, has a significant influence on CO₂e emissions and thus on absolute fuel consumption.

- **Tier 1:** Seating capacity is recorded for each individual flight based on the exact configuration of the aircraft type used.
- **Tier 2:** The seating capacity of an aircraft type is recorded as an average at airline level. This means that if, for example, an airline has several Boeing 777-200ERs in its fleet, half of which have 280 seats and half of which have only 260 seats, then at least the weighted average of 270 seats must be used in the calculation.

2.2.8. Passenger load factor

Seating capacity, when combined with load factor, determines the actual passenger payload carried, which – together with the payload generated by baggage – is a key factor in the flight's fuel consumption and emissions.

Timing of load factor data: Although the flight is still in the future at the time of booking by the passenger, the load factor must be estimated, with the highest degree of probability, on the basis of the most recent past. To this end, for existing flights on the same city pair, the load factor data for the flight and the airline from the most recent previous year are used, for which official data services such as ICAO-TFS and others provide data. For new flights that an airline is offering for the first time in the current year, an approximate load factor is applied based on the most recent figure the airline was able to achieve in the relevant flight region (or, if unknown, the airline's global average) on routes of a similar length.

- **Tier 1:** Passenger load factor is included individually for each flight in the calculation of payload and thus of fuel consumption.
- **Tier 2:** If the data sources do not report passenger load factor for an individual flight (combination of flight number and flight date), then load factor data based on averages at the following levels may be used as a substitute, in the following order:
 - Load factor by airline and aircraft type on the city pair, annual average.
 - Load factor by airline on the city pair, averaged over a year.
 - Load factor by airline, global average, broken down into domestic and international (if not available: global).
- **Tier 3:** Load factor based on the global average of all airlines, broken down by short-haul, medium-haul and long-haul (values from the literature).

2.2.9. Differentiation by cabin class

Aircraft can be configured differently depending on the customer segment served. Not only do the number of seats and the spacing between rows vary, but so does the ratio of First Class,

Business, Premium Economy and Economy seats. The different classes take up varying amounts of space per passenger, which means that different proportions of the absolute fuel consumption must be allocated to the respective seat class – Economy the least, First Class the most.

Unlike the factors mentioned so far, seat classes no longer influence an aircraft's payload (which is determined by the number of passengers, resulting from load factors (see section 2.2.8) and seating configuration (see section 2.2.7)). Therefore, the seat classes can simply be applied to the average CO₂e footprint of the entire flight using a multiplier at the end of the calculation method. The multipliers express the space required by a seat in the respective class in relation to the space required by a seat in the lowest class (Economy).

To map this factor in detail across all flights, the cabin layout of every single aircraft would need to be measured, which is not feasible in practice. However, it appears that, globally, the multipliers for seat classes differ significantly only between single- and double-aisle aircraft¹³; within these two groups of aircraft, however, they are generally consistent, with only minor variations. IATA has therefore, in its CO₂e calculation standard, most recently evaluated globally applicable multipliers for these two groups of aircraft and prescribed them for the calculation.

For these reasons, the KlimaLink flight method takes seat classes into account as follows.

- **Tier 1:** Application of seat class multipliers derived for the respective aircraft type from the cabin layout of the relevant airline. Weighted averages of the multipliers may also be used if an airline operates the same aircraft type multiple times but with different layouts.
- **Tier 2:** Application of globally valid seat class multipliers categorised into single-aisle and double-aisle aircraft in accordance with the IATA method and using IATA data.

2.2.10. Additional cargo capacity

Additional cargo capacity affects fuel consumption in the same way as seating capacity. Available data sources report the additional cargo capacity of an airline's individual aircraft in tonnes of cargo capacity, in the same way as seating capacity data. For this reason, additional cargo capacity is recorded in the KlimaLink flight method in the same way as passenger capacity.

- **Tier 1:** Cargo capacity is recorded for each individual flight based on the exact configuration of the aircraft type deployed.
- **Tier 2:** The cargo capacity of an aircraft type is recorded as an average at airline level. This means that if, for example, an airline has several Airbus A340s in its fleet and 50 per cent of the aircraft have 12 tonnes of additional cargo capacity whilst 50 per cent have only 6 tonnes, then at least the weighted average of 9 tonnes must be used in the calculation.

¹³ Single-aisle / narrow-body: aircraft, generally used for short- and medium-haul flights, with a single aisle. Double-aisle / wide-body: wider, larger aircraft with two aisles, used for long-haul flights.

2.2.11. cargo utilisation

As with passenger load factor, the load factor for additional cargo also has a direct impact on the payload and thus on the absolute and, subsequently, specific fuel consumption. The KlimaLink method is defined for cargo load factor in the same way as for passenger load factor. This applies both to the timing of the load factor data for cargo and to the three tiers, which, in descending order of accuracy, ensure that the method returns a defined value for all flights in practice.

2.2.12. Freight discount, destination regions

Cargo transported as additional cargo results in increased fuel consumption, which can be deducted from the figures for air passengers, provided that the cargo transported is not directly related to the journey. This leads to a reduction in the payload attributable to the air passengers. Consequently, the specific CO₂e emissions per passenger are reduced.

On tourist flights, however, additional cargo is often used to supply the destination areas, which are utilised by the passengers on board. Consequently, the CO₂e deduction for passengers can only be applied to a limited extent in this case. There is currently no quantitative literature on the proportion of additional cargo on tourist flights that serves tourist purposes (e.g. the import of certain foodstuffs). However, as the overall effect on CO₂ emissions is relatively small, the KlimaLink method applies a flat-rate value at this point, which thus applies to all tourist destinations served by these flights.

Based on this flat rate, a simple estimate assumes that 50 per cent of the additional cargo is classified as tourism-related and 50 per cent as non-tourism-related.

The total emissions of a flight are calculated using the full amount of cargo carried. However, when allocating emissions to individual passengers, only the emissions associated with transporting the portion of the cargo assumed to be for tourism purposes are taken into account; the non-tourism portion is not included.

2.2.13. Upstream stage of kerosene production (well-to-wheel)

When calculating emissions from air travel, the well-to-wheel emission factors for kerosene must also be taken into account. Three areas are relevant here:

1. Oil extraction in the country of origin: (drilling, extraction, production, flaring) and transport to the refinery.
2. Refinery: processing of crude oil into kerosene.
3. Transport of kerosene from the refinery to the airport.

These emissions must be included because, as a paying customer, the passenger bears a significant share of the CO₂ emissions in these areas.

The KlimaLink flight method applies the system boundaries for kerosene in accordance with the WTW (well-to-wheel) approach, as distinct from the TTW (tank-to-wheel) approach, as described in DIN EN 16258. It thus incorporates upstream emissions into the method. For these

emissions, just as for the CO₂ emissions from the flight at altitudes below 9 km, the non-CO₂ multiplier must not be applied.

2.2.14. Inclusion of non-CO₂ emissions

As described in the section 1.4.3, in addition to CO₂ emissions, there are other climate effects that contribute to global warming. On average, these climate effects have an impact at cruising altitude that is three times greater than the effects of CO₂ alone. Accordingly, one tonne of CO₂ emitted, together with non-CO₂ emissions in the upper troposphere and lower stratosphere at cruising altitudes of over 9 km, has the same warming effect on the climate as three tonnes of CO₂ alone.

The calculation method takes into account the additional climate impact of non-CO₂ emissions, but only for the portion of the flight at altitudes above 9 km. For short-haul flights, this proportion is lower than for long-haul flights and may even be zero, provided that the aircraft on short-haul flights do not climb above 9 km or are unable to fly at such altitudes (e.g. many turboprop aircraft). Only the fuel consumption – and thus the CO₂ emissions – at altitudes above 9 km need to be determined, and only these should be multiplied by the adjustment factor for non-CO₂ emissions.

2.2.15. Data quality and updates

The timeliness and quality of the input data are important for ensuring that the results obtained using KlimaLink's sophisticated method are of the appropriate quality.

2.2.15.1. Quality

The input data in the KlimaLink standard meets the quality requirements of independence and verification.

Independence: The data should come from independent third-party sources (commercial data services, public authorities and other official bodies such as the UBA, Eurocontrol, etc.), as well as from peer-reviewed scientific publications. It must not come directly from airlines, aircraft manufacturers or trade associations without having been verified by one of the aforementioned independent third parties.

Verification: The data must have been checked by the data provider for at least plausibility and consistency.

2.2.15.2. Updates

The following update intervals apply to the various data sets when using the emissions data platform.

- Flight schedule data: monthly.
- Aircraft types: for each new aircraft type upon its appearance in flight schedules, including the implementation of standard fuel consumption figures in a suitable computer model.
- Airline fleet compositions: annually.
- Seating capacity, additional cargo capacity: annually.

- Load factors: annually (Tier 1 and 2), every five years (Tier 3).
- Other scientific data, e.g. for non-CO₂, kerosene upstream chain: as soon as significant new and quantified scientific findings are available that have been consistently confirmed by publications over a three-year period and have been incorporated into the specialist literature.

3. Input variables and calculation formulas

3.1. Variables

Variable	Description	Value / Unit
Distances		
D_G	Great circle distance of a city pair	km
D_R	Surcharge for detours, flat-rate, graded according to great circle distance	km
D	Distance of a city pair's flight route (great circle + de-tour)	km
D_o	Standard distance above the flight distance D	km
D_u	Standard distance below the flight distance D	km
Aircraft weights and loads		
TOW	Take-off weight, the aircraft's take-off weight	tonnes
OEW	Operational Empty Weight, the aircraft's empty weight	tonnes
NL	Payload (passengers, baggage and additional cargo)	tonnes
PAX	Number of passengers on board a flight	-
S_c	Seating capacity on board the aircraft (number of available seats, total across all seating classes)	-
C_c	Cargo capacity for additional cargo (in addition to passengers' luggage)	tonnes
LF_p and LF_c	Load factor for passengers and cargo (additional cargo)	%
NL_{80}, NL_{20}	Payload in cases where the utilisation rates for both passengers and cargo are 80% and 20% respectively.	tonnes
Fuel consumption and emission factors		
$F_{NL,D}$	Absolute fuel consumption of the flight in question, depending on the payload NL and the flight distance D	kg
$F_{NL20,D}$ $F_{NL80,D}$	Absolute fuel consumption for the flight in question, at 20 per cent and 80 per cent utilisation of the total payload, over the flight distance D	kg
$CO_{2,PAX}$	Specific CO_2e emissions per passenger	kg
EF_{TTW}	Emission factor for converting fuel consumption into CO_2 emissions within the 'Tank to Wheel' (TTW) system boundaries	kg CO_2 / kg fuel
EF_{WTW}	Emission factor for converting fuel consumption into CO_2 emissions within the 'Well to Wheel' (WTW) system boundaries	kg CO_2 / kg fuel

F_{Taxi}	Constant for fuel consumption per passenger whilst the aircraft is taxiing at airports before take-off and after landing	kg
	Other factors	
f_{winglet}	Factor for the percentage reduction in absolute fuel consumption due to winglets	%
$f_{\text{cabin class}}$	Factors for differentiating specific CO_2 emissions per passenger by seat class (Economy, Business, First Class)	-
$f_{\text{destination region}}$	A factor that reduces the deduction from specific fuel consumption per passenger for additional cargo, as this cargo benefits both the destination and the passenger.	50%
	Climate impact of contrails etc. (non-CO_2)	
f_{NCO_2}	A factor representing the climate impact of all emissions (CO_2 and $\text{non-CO}_2\text{e}$) relative to the CO_2 emissions alone from flights at altitudes above 9,000 metres. At lower altitudes, the factor is always set at 1.	3
f_{cruise}	Proportion of the flight distance at altitudes above 9,000 m relative to the total flight distance; necessary for determining the climate impact of non-CO_2 emissions	%
CO_2e	CO_2 equivalent emissions	kg
$\text{CO}_2\text{e}_{\text{PAX}}$	Specific CO_2 equivalent emissions (per passenger)	kg

3.2. Calculation formula

The absolute fuel consumption F of a specific aircraft type on a given flight is generally calculated as follows:

$F_{\text{TOW}, D} = f(\text{TOW}, D)$ where TOW = take-off weight;

D = flight distance;

$D = \text{DG} + \text{DR}$ where DG = great circle distance, DR = roundabout (according to ICAO)

f = function, calculated using a dedicated computer model (see II.B.5)

$\text{TOW} = \text{OEW} + \text{NL} + \text{taxi fuel} + \text{trip fuel} + \text{reserve fuel}$

where OEW = Operational Empty Weight of the aircraft hardware, depending on the aircraft type

NL = payload (sum of the weight of passengers, their luggage and additional air cargo as supplementary cargo)

3.2.1. Payload and distance: key overarching variables for fuel requirements

An aircraft's take-off weight (TOW) (comprising the aircraft's structure, the payload (NL) and the fuel on board) and the distance are the two key variables controlled by the aircraft operator that determine the aircraft's fuel consumption on a flight.

Although KlimaLink requires the two key variable factors – distance and payload – to be plotted for each aircraft type within the aforementioned non-linear interdependence (see section: Fuel weight, flight profile and altitude), it subsequently allows for an approximation. This is achieved by first having a computer model precisely calculate a large number of finely meshed combinations of various standard payloads and distances for each aircraft type and then interpolating the calculated fuel consumption for the respective flight of that aircraft type from these precise values (value matrix).

3.2.2. Precise computer model calculation for the value matrix, followed by interpolation

In practice, this means that the possible distances for a particular aircraft type are first broken down into standard distances (see the section on flight distance). For each of the standard distances—one above and one below the actual distance D of the flight in question (D_o and D_u)—the fuel consumption is then determined for payloads of 80 per cent and 20 per cent (NL80 and NL20). From these four precisely calculated combination values for a particular aircraft type, the fuel consumption for the actual distance D and actual payload NL can then be linearly interpolated with good accuracy.

Simpler methods, which use only various standard distances, each with an average load factor, to calculate a base consumption for a given distance, and which then apply the actual cargo and passenger load factors merely as multipliers to this base consumption, are, by contrast, too prone to error because they do not take the above-mentioned dependencies into account.

The definitions and formulae for implementing the Klimalink Flight Method are therefore as follows:

3.2.3. Definitions

NL	=	$PAX * 100kg + C$;	where NL = payload; C = additional cargo
PAX	=	$S_c * LF_p$;	where S_c = seating capacity; LF_p = passenger load factor
C	=	$C_c * LF_c$	where C_c = cargo capacity; LF_c = load factor for additional cargo;
NL ₈₀	=	$PAX_{(at a passenger load factor of 80\%)} * 100 kg + C_c * 80\%$;	
NL ₂₀	=	$PAX_{(at an LFp of 20\%)} * 100kg + C_c * 20\%$;	

3.2.4. Calculation of fuel consumption, standard distances and standard payloads

Firstly, the standard values for FNL20 and FNL80 must be determined for each aircraft variant using a computer model of the quality class specified in this standard for fuel calculation.

Once FNL20 and FNL80 have been calculated for all standard distances and for all possible aircraft types using the two formulae above, the fuel consumption matrix is complete.

From this, the required absolute fuel consumption of a flight, FNL, D, is derived by linear interpolation from the four individual values of the fuel consumption matrix F(NL20, Du), F(NL20, Do), F(NL80, Du) and F(NL80, Do) in three steps as follows:

$$F_{NL20,D} = \left(\frac{(F_{NL20,Do} - F_{NL20,Du})(D - D_u) + F_{NL20,Du}(D_o - D_u)}{(D_o - D_u)} \right) * f_{winglet}$$

$$F_{NL80,D} = \left(\frac{(F_{NL80,Do} - F_{NL80,Du})(D - D_u) + F_{NL80,Du}(D_o - D_u)}{(D_o - D_u)} \right) * f_{winglet}$$

$$F_{NL,D} = \frac{(F_{NL80,D} - F_{NL20,D})(NL - NL_{20})}{(NL_{80} - NL_{20})} + F_{NL20,D}$$

3.2.5. Calculation of specific CO₂e emissions per seat class, within the WTW boundaries

The following formula is used to calculate the specific CO₂ emissions of a passenger, initially within the Tank-to-Wheel (TTW) system boundaries:

$$CO_{2ePAX,TTW} = F_{NL,D} * EF_{TTW} / PAX$$

To calculate the associated non-CO₂ emissions, the specific CO₂ emissions (kg CO₂ per passenger on a flight) must be supplemented by the additional climate impacts resulting from the flight's non-CO₂ emissions (contrails, cirrus clouds, ozone depletion, methane cooling, etc.).

$$CO_{2ePAX,TTW} = (CO_{(2)PAXTTW} * (1 - f_{cruise})) + (CO_{2PAXTTW} * f_{cruise} * f_{NCO_2})$$

Finally, the emissions from the upstream chain of kerosene production must be taken into account in order to convert the specific CO₂e emissions from the TTW (Tank to Wheel) system boundaries to the desired WTW (Well to Wheel) system boundaries, as well as to differentiate the specific CO₂e emissions by cabin class.

$$CO_{2ePAX,WTW,cabin\ class} = (CO_{2ePAX,TTW} + (F_{NL,D} / PAX) * (EF_{WTW} - EF_{TTW})) * f_{cabin\ class}$$

This completes the calculation, which, taking into account all factors specified in the KlimaLink Standard, provides the specific CO₂e emissions per passenger in their cabin class within the desired WTW system boundaries.

KlimaLink makes the calculated values available to all tourism businesses via an emissions data platform.

Futouris, in collaboration with Inatour, has initiated and led the dialogue processes with all stakeholders – and in particular with the providers of similar standards such as IATA, Travalyst, etc. – and has analysed and assessed the results from both a scientific and a tourism perspective.

This document was produced as part of the ‘Climate-Conscious Travel’ project, in which all companies, associations and organisations within the tourism sector are invited to participate. The project is funded and implemented by KlimaLink e.V.

In preparation for the EU ‘Count Emissions’ Regulation, KlimaLink successfully had the 2026 calculation standard for air, rail and car/bus travel verified for compliance with ISO 14083 by GUTCert¹⁴, an accredited certification body in Berlin. The certificate is attached.

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¹⁴ <https://www.gut-cert.de/en/home-en>

Version changes

Date	Version	Chapter	Change [...]	Responsible
22 July 2026	1.1	Foreword	Added: Introductory text	SA/SL
18 September 2023	1.0	All	Initial version	HZ/DB/SL

DB Dr Dietrich Brockhagen, atmosfair gGmbH
 HZ Prof. Dr Harald Zeiss, Institute for Sustainable Tourism GmbH
 SL Swantje Lehnert, Futouris e.V.
 SA Saskia Sánchez, KlimaLink e.V.

Berlin, July 2026

Resultat

In Rahmen eines vereinbarten Verfahrens wurden die folgenden Berechnungsstandards der Organisation

KlimaLink e.V.

am Standort Lietzenburger Straße 99, 10707 Berlin

geprüft:

„KlimaLink Standard KFZ“
„KlimaLink Standard Bus“
„KlimaLink Standard Bahn“
„KlimaLink Standard Flug“

Die Berechnungsstandards für Transport „KlimaLink Standard KFZ“, „KlimaLink Standard Bus“, „KlimaLink Standard Bahn“ und „KlimaLink Standard Flug“ erfüllen die Anforderungen der für den Berechnungszweck relevanten Normkapitel aus den Kapiteln 3, 5, 6, 7, 8, Anhang A, E, F der ISO 14083:2023.

Die Einzelheiten zum Umfang der Prüfung sind im Anhang dargelegt. Die Berechnungsstandards erfüllen alle relevanten Anforderungen gemäß den im Anhang aufgeführten Normkapiteln. Die für die Berechnung verwendeten Emissionsfaktoren basieren auf veröffentlichten Informationen oder anerkannten, glaubwürdigen Quellen. Die angewandte Berechnungsmethode wurde auf Eignung und Plausibilität überprüft.

Die für die Prüfung erforderlichen Informationen wurden in den Dokumenten „2027_07 KFZ KlimaLink Standard V2.0.pdf“, „2027_07 Bus KlimaLink Standard V2.0.pdf“, „2027_07 Bahn KlimaLink Standard V2.0.pdf“ und „2027_07 Flug KlimaLink Standard V1.1.pdf“ vom 22.07.2026 klar dargelegt.

Die Prüfung wurde gemäß eines geeigneten Verfahrens entsprechend den Vorgaben der ISO 14064-3:2020-05 Anhang C durchgeführt.

Basis des Ergebnisses ist der Prüfbericht mit der Nr. C-26-25274-Tool.

Berlin, 26.08.2026



Prof. Dr.-Ing. Jan Uwe Lieback
Geschäftsführer

Nr. C-26-25274-Tool

Annex zu C-26-25274-Tool

Details zu Prüfungsinhalten

ISO 14083:2023 mit folgenden Kapiteln:

3.1.1, 3.1.2, 3.1.3, 3.1.5, 3.1.6, 3.1.7, 3.1.8, 3.1.11, 3.1.12, 3.1.14, 3.1.16, 3.1.17, 3.1.18,
3.1.19, 3.1.20, 3.1.22, 3.1.23, 3.1.24, 3.1.25, 3.1.27, 3.1.30, 3.1.31, 3.2.1, 3.2.2, 3.2.3,
3.2.4, 3.2.5, 3.2.7, 3.2.9, 3.3.1, 3.3.2, 3.3.3.2, 3.3.3.3, 3.3.3.4, 3.3.4, 3.3.8, 5.3.2, 5.4.1,
5.4.2, 5.4.3, 5.4.4, 5.6.2, 5.6.4, 6.1, 6.3.2, 7.2, 7.3, 8.3.2, 8.3.3, 8.4.2, 8.4.3, 8.4.5.2, 8.4.7,
A, A 3.1, A 3.2, A 4.2, A 5, E, E 2, E 3.1, E 3.2, E 5, F, F 2, F 3.1, F 4.5.